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# Journal of Autism and Developmental Disorders

## Measuring Changes in Social Communication Behaviors: Preliminary Development of the Brief Observation of Social Communication Change (BOSCC) --Manuscript Draft--

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<b>Abstract:</b>	<p>The psychometric properties and initial validity of the Brief Observation of Social Communication Change (BOSCC), a measure of treatment response for social-communication behaviors, are described. The BOSCC coding scheme is applied to 177 video observations of 56 toddlers and preschoolers with ASD with minimal language. The BOSCC has adequate to excellent inter-rater and test-retest reliability as well as convergent validity with other measures of language and communication skills. BOSCC scores demonstrate more change than Autism Diagnostic Observation Schedule Calibrated Severity Scores (ADOS CSS) over the same period of time. This initial study is a first step toward the development of a novel outcome measure for social-communication behaviors that has applications to clinical trials and longitudinal studies.</p>	

Running Head: BOSCC

Measuring Changes in Social Communication Behaviors: Preliminary Development of  
the Brief Observation of Social Communication Change (BOSCC)

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## Abstract

The psychometric properties and initial validity of the Brief Observation of Social Communication Change (BOSCC), a measure of treatment response for social-communication behaviors, are described. The BOSCC coding scheme is applied to 177 video observations of 56 toddlers and preschoolers with ASD with minimal language. The BOSCC has adequate to excellent inter-rater and test-retest reliability as well as convergent validity with other measures of language and communication skills. BOSCC scores demonstrate more change than Autism Diagnostic Observation Schedule Calibrated Severity Scores (ADOS CSS) over the same period of time. This initial study is a first step toward the development of a novel outcome measure for social-communication behaviors that has applications to clinical trials and longitudinal studies.

Keywords: Autism, Autism Spectrum Disorder (ASD), Autism Diagnostic Observation Schedule (ADOS), Brief Observation of Social Communication Change (BOSCC), Social Communication, Restricted and Repetitive Behaviors and Interests (RRB), Toddlers, Preschoolers

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Measuring Changes in Social Communication Behaviors: Preliminary Development of the Brief  
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## Abstract

The psychometric properties and initial validity of the Brief Observation of Social Communication Change (BOSCC), a measure of treatment response for social-communication behaviors, are described. The BOSCC coding scheme is applied to 177 video observations of 56 toddlers and preschoolers with ASD with minimal language. The BOSCC has adequate to excellent inter-rater and test-retest reliability as well as convergent validity with other measures of language and communication skills. BOSCC scores demonstrate more change than Autism Diagnostic Observation Schedule Calibrated Severity Scores (ADOS CSS) over the same period of time. This initial study is a first step toward the development of a novel outcome measure for social-communication behaviors that has applications to clinical trials and longitudinal studies.

There is a critical need for the development of outcome measures that assess changes in social communication behaviors. Though most treatments for Autism Spectrum Disorder (ASD) focus on improvements of social communication behaviors (Rogers & Vismara, 2008), the field of ASD intervention research in particular has struggled to find measures of treatment response that adequately capture changes in these behaviors (Anagnostou et al., 2015). Changes in social communication behaviors are often subtle and context-specific, making it difficult to find measures that are sensitive enough to capture small, though potentially meaningful, changes (Anagnostou et al., 2015). Moreover, few of the measures available are flexible or standardized enough to be used across sites and studies. A recent review noted that out of 200 behavioral intervention trials for ASD, over 300 different tools were used to measure treatment response (Bolte & Diehl, 2013). Sixty percent of these tools were used in only a single study, with only three tools used in more than 2% of studies (Bolte & Diehl, 2013). A panel of ASD experts determined that only a handful of existing measures are appropriate for identifying treatment response in ASD (Anagnostou et al., 2015; Scahill et al., 2015).

Yet, instruments currently used have significant limitations (Anagnostou et al., 2015; Scahill et al., 2015). Researchers often use treatment response measures that are study-specific. For example, researchers create measures that capture the frequency of a specific operationalized behavior that is targeted in treatment, such as joint attention (Kaale, Smith, & Sponheim, 2012). Although these measures may be helpful to identify change in single behaviors in particular studies, they do not capture broader social communication changes or changes related to a range of ASD symptoms. Other measures used are intended for screening, diagnosis or measuring symptom severity (Anagnostou et al., 2015; Scahill et al., 2015). As such, these measures are usually not sufficiently sensitive for measuring change over short periods of time (e.g., months



rather than years). For example, the Autism Diagnostic Observation Schedule (Lord, Luyster, Gotham, & Guthrie, 2012; Lord et al., 2012), a measure intended for diagnostic purposes, has frequently been applied as an outcome measure. Using raw scores from the ADOS has generally been unsuccessful in assessing changes (Owley et al., 2001), perhaps because ADOS raw scores are not intended for use as interval data or for measuring change. When changes have been identified with ADOS raw scores, the clinical significance of these changes may be limited since changes are also present in treatment-as-usual conditions (Green et al., 2010). The ADOS calibrated severity score (CSS; Esler et al., 2015; Gotham, Pickles, & Lord, 2009) may be useful in identifying changes over the course of years (Gotham, Pickles, & Lord, 2012; Lord, Luyster, Guthrie, & Pickles, 2012), but it has been less successful in identifying changes over shorter periods of time (Dawson et al., 2010; Shumway et al., 2012; Thurm, Manwaring, Swineford, & Farmer, 2015). Similarly, analyses of the Autism Diagnostic Interview, Revised (Lord, Rutter, & Couteur, 1994), a parent interview used for diagnostic assessment, has proven useful in identifying trajectories of change over the course of years (Lord, Bishop, & Anderson, 2015), but its utility over shorter periods of time is unclear. A further hindrance to using measures such as the ADOS and ADI-R is that they generally require significant training to learn to administer and score reliably, as well as significant time from patients and clinicians, limiting feasibility in large-scale, multi-site studies.

An additional limitation to measures commonly used in clinical trials is the reliance on caregiver or clinician report (Anagnostou et al., 2015; Bolte & Diehl, 2013). Placebo effects are particularly strong for caregiver or clinician report measures, such as Clinical Global Impressions (CGI; Busner & Targum, 2007). These effects may even outweigh more subtle changes that occur over time or in response to interventions (Guastella et al., 2015; Lord,

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4 Luyster, Guthrie, & Pickles, 2012; Owley et al., 2001). In a recent paper, clinician-report  
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6 measures of response to treatment were more related to caregiver belief that the child was  
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8 receiving the experimental treatment than to the treatment itself (Guastella et al., 2015). A  
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10 second, related issue that limits measurement of treatment effects is “unblinding,” which is often  
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12 inherent in caregiver or clinician reports. For example, in treatments that have significant side  
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14 effects, families and clinicians are frequently aware if their child is experiencing these other  
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16 changes. Third, measures used to capture a broad range of social-communication behaviors are  
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18 often confounded by co-occurring intellectual deficits, behavior or language problems (Hus,  
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20 Bishop, Gotham, Huerta, & Lord, 2013). The influence of these confounds may make it difficult  
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22 to disentangle meaningful changes in ASD-specific social-communication behaviors from other  
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24 non-ASD-specific symptoms.  
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31 The limitations of currently used measures interfere with the ability of clinicians and  
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33 researchers to measure effectiveness of interventions, perhaps contributing to the phenomenon  
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35 that few ASD interventions actually meet standard criteria for efficacy (Chambless & Hollon,  
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37 1998; Danial & Wood, 2013). The Brief Observation of Social Communication Change  
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39 (BOSCC) is an initial attempt to address these limitations. The BOSCC is a new measure  
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41 developed to identify changes in social-communication behaviors over relatively short periods of  
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43 time (i.e., months as opposed to years) by quantifying subtleties in both the frequency and the  
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45 quality of specific behaviors. The goal of the BOSCC is to provide researchers and clinicians  
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47 with an outcome measure that is flexible, easy to code, and minimally-biased by parental or  
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49 clinician report. The BOSCC is flexible enough to be used across a variety of settings (e.g.,  
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51 across multi-site studies, in clinics or at home) and is coded by a minimally trained  
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53 clinician/researcher who is blind to the child’s treatment status.  
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The BOSCC described in this work is applicable to minimally verbal, young children. The BOSCC is a coding scheme that was developed by modifying and expanding codes from the ADOS-2 (Lord, Luyster, Gotham, & Guthrie, 2012) to capture more subtle variations in behaviors. In this initial paper, we apply the BOSCC to children with Autism Spectrum Disorder (ASD), although applications of the BOSCC may be extended to other disorders with deficits in social-communication (e.g., Language Impairments, Social/Pragmatic Communication Disorder, and Social Anxiety Disorder). The goal of this paper is to provide preliminary evidence for the utility of the BOSCC as a treatment response measure. The specific aims are to describe the psychometric properties of the BOSCC and to provide initial evidence for its validity.

## Method

*Participants.* Fifty-six children (44 males) with a Best Estimate Clinical Diagnosis (BEC; Anderson, Liang, & Lord, 2014) of an Autism Spectrum Disorder (ASD) were included in this study. Diagnoses of ASD were determined based on thorough diagnostic evaluations, including administration of the Autism Diagnostic Interview-Revised (ADI-R; Lord et al., 1994) and the Autism Diagnostic Observation Schedule (ADOS-2; Lord, Luyster, Gotham, & Guthrie, 2012; Lord et al., 2012). All participants had elected to join various treatment studies (Kasari, Gulsrud, Wong, Kwon, & Locke, 2010; Rogers et al., 2012; Wetherby et al., 2014) depending on which studies were available at the time and were then randomized into a treatment condition at the University of X (X; n=49) or Y (Y; n=6), with the exception of one participant. Data from this one child was extracted from an existing database of children whose parents had provided written informed consent for their child's clinical information/assessments to be included in an Institutional Review Board (IRB)-approved database. For the purposes of this initial work, which

focuses on the validity and reliability of the BOSCC, specific treatment conditions are not explored; future work will address this question.

All children included in the study were between 1 and 5 years of age with minimal spontaneous language (simple phrase speech or less), as is appropriate for the current BOSCC coding scheme (described below). Sixty-one percent ( $n=34$ ), 9% ( $n=5$ ), and 9% ( $n=5$ ) of participants identified as Caucasian, African American, or Other (Pacific Islander, Biracial, or Other), respectively; 21% ( $n=12$ ) did not provide race information. Eleven percent ( $n=6$ ) of the participants identified as Hispanic; 7% ( $n=4$ ) did not provide ethnicity information. Most participants ( $n=53$ ) provided information about the mother's level of education; 57% ( $n=30$ ) of mothers had completed 4 years of college or more, 30% ( $n=16$ ) of mothers had completed some college, 11% ( $n=6$ ) had a high school diploma, and 2% ( $n=1$ ) had not completed high school. See Table 1 for demographic information.

[Insert Table 1]

*Primary measure.*

*BOSCC.* For the purposes of assessing the initial psychometric properties and validity, the BOSCC coding scheme was applied to 10-minute videos of free-play interactions (coded in two 5-minute segments) between a parent and a child, gathered over the course of the child's participation in an intervention trial. Videos were available for children over an average of 5.9 months ( $\pm 3.1$  months). Children were between the ages of 12 and 56 months at their first observation (mean=29 month  $\pm$  11 months) and between the ages of 18 and 62 months at their last observation (mean=35 months  $\pm$  11 months).

The original BOSCC coding scheme consisted of 16 items coded on a 6-point scale from 0 (abnormality is not present) to 5 (abnormality is present and may significantly impair

functioning). Nine items related to social communication behaviors; one of these items was subsequently eliminated (see Preliminary Analyses below). One item related to play and three items related to restricted, repetitive behaviors/interests seen in ASD. Three items were used as markers of other abnormal behaviors often seen in ASD, although these behaviors were rarely observed in this sample of children playing with their parent(s).

Each BOSCC item is coded using a novel, empirically-based decision tree, which captures detailed information about specific behaviors, including, for example, information about its frequency and quality (see Supplementary Figure 1 for example item). At each branch of the decision tree, the coder answers a question about the child's behavior before proceeding on to the next question or arriving at a code. For example, the directed vocalizations item first asks whether the child directs vocalizations to another person (branch 1), then asks whether this ever occurs beyond directed echoed or highly routinized speech (branch 2), how often these more flexible directed vocalizations occur (branch 3), in what pragmatic contexts these occur (branches 4 and 5), and in how many activities (branch 6). The BOSCC is coded in two 5-minute segments (first and second five-minute segments of a 10-minute video). The initial coding process relied on viewing each video segment (5-minutes) one time and then coding. Over the course of development, this process was modified such that each video segment was watched and coded twice, with the second codes used for analyses in this study. Observing and coding each segment twice resulted in greater accuracy in capturing behaviors, higher reliability amongst coders, and greater confidence in coding decisions. Coding a BOSCC video takes a trained coder about 30 minutes to complete.

Coders of data presented here were one clinical psychology graduate student, one psychologist, one psychiatrist, and several research assistants. All coders were blind to the

child's treatment status as well as treatment time point. Coders obtained inter-rater agreement standards (3 consecutive videos, across both segments A and B, with no more than 3 items with more than 1 point disagreement AND within 3 points across summed totals for all items) before coding independently. Participants had between 1 and 8 videos suitable for BOSCC coding and a random sub-sample (approximately every 6<sup>th</sup> video) was chosen for coding by multiple coders in order to ensure that inter-rater agreement was retained over time (See below). During consensus meetings for these multiply coded videos, coders determined final consensus codes; data presented here uses consensus codes when applicable.

#### *Additional Measures.*

As part of participation in the intervention trials, children completed several assessments, including assessments of cognitive functioning, adaptive functioning, and diagnostic assessments. These additional measures provided an opportunity to explore the convergent validity of the BOSCC. See Table 2 for a summary of measures included.

*Adaptive Functioning.* The Vineland Adaptive Behavior Scales (VABS; Sparrow, Cicchetti, & Balla, 2005) was completed with the parents of a subset of children (n=31) at two or more time points. The VABS is a parent interview of adaptive functioning that provides standard scores in the domains of socialization, communication, daily living, and motor skills as well as an overall adaptive behavior composite standard score (ABC). See Table 1 for information about VABS Domain scores at the initial observation.

*Cognitive Functioning.* Children were administered either the Mullen Scales of Early Learning (MSEL; Mullen, 1995) or the Differential Abilities Scales (DAS; Elliot, 2007), depending on the child's ability level. The MSEL (collected from 36 children at two or more time points) provides

standard scores in the domains of expressive language, receptive language, visual reception, and fine motor skills. The DAS provides standard scores in the domains of verbal and nonverbal cognition. Ratio IQs were calculated due to the inability to calculate norm-referenced standard scores in some children because the child's age exceeded standard cut-offs and/or their developmental levels were too low to be calculated using standard metrics (see Bishop, Guthrie, Coffing, & Lord, 2011). None of the children received the DAS at more than one time point. As a result, only the participants with multiple MSEL scores were explored in analyses addressing change in cognitive scores. See Table 1 for information about cognitive functioning at the first observation.

*ASD Symptoms.* The Autism Diagnostic Observation Schedule, 2<sup>nd</sup> Edition (ADOS; Lord, Luyster, Gotham, Guthrie, 2012; Lord et al., 2012) was administered to a subset of children (n=41) at two or more time points. The ADOS obtains information about a diagnosis of ASD through direct observation by a clinician. All clinicians involved in administering the ADOS established research reliability on the measure prior to administration. The ADOS provides Calibrated Severity Scores (CSS) for the algorithm total (CSS Overall) and domain severity scores in the areas of Social Affect (CSS SA) and Restricted and Repetitive Behavior (CSS RRB; Esler et al., 2015; Gotham et al., 2009). These scores provide a cross-module comparison that takes into account language level and age. See Table 1 for information about ADOS CSS at the first observation.

*Clinical Global Impression-Improvement (CGI).* The CGI is a measure used by clinicians to evaluate whether an individual is responding to treatment (Busner & Targum, 2007). Clinicians rate the participant's level of improvement on a 7-point scale ranging from "very much

improved” (1) to “very much worse” (7). The CGI was collected on six children who participated in an intervention trial at Y, for whom we also had independently rated BOSCCs.

[Insert Tables 2]

### *Preliminary Analyses.*

Over several versions of the BOSCC coding scheme, numerous codes and coding structures were generated and tested. Other studies have used a preliminary version of the BOSCC (from February 2014; Fletcher-Watson et al., 2015; Kitzerow, Teufel, Wilker, & Freitag, 2015). The work presented here used an updated version of the BOSCC coding scheme with modifications to most codes (version from September 2015). Given the goals of the BOSCC, a uniform distribution over the coding range for items was desirable. Item codes were re-written over several versions to better achieve this distribution. Figure 1 depicts the averaged (across segment A and B) item distributions. Since many children with ASD do not show all of the coding ranges for RRBs (Kim & Lord, 2010), we did not expect normal or uniform distributions for the three items related to these behaviors, namely sensory interests, hand/finger mannerisms, and restricted/repetitive behaviors/interests. Few children were scored as having Other Abnormal Behavior (Supplementary Figure 2) and these items were not included in subsequent analyses.

A correlation matrix was constructed which indicated that the correlation between the Shared Enjoyment and Facial Expressions items exceeded 0.7, suggesting a substantial overlap in the behaviors captured by these codes. Facial Expressions had a more uniform distribution across the coding range (0-5) and was thus retained while Shared Enjoyment was eliminated from the measure and subsequent analyses.

### *Statistical Analysis and Repeated Measures Design.*



*Item-level Factor Analyses.* Exploratory Factor Analyses were conducted for the 12 BOSCC items (Shared Enjoyment removed, see above). For the factor analyses, the scores for the three items with skewed distributions (sensory interests, hand/finger mannerisms, and restricted/repetitive behaviors/interests) were collapsed to 3 or 4 categories and treated as ordinal scores in the exploratory factor analysis. Analyses were undertaken in Mplus (Muthen & Muthen, 1998-2012) using a promax oblique rotation, taking into account the multiple codings by using the complex survey adjustment with the child as the cluster-level unit.

*Reliability and Validity Analyses of Domain Scores.* Averaged sums for items in the factors (domains) defined by the EFA results were calculated as well as an average sum for all ASD items (1-12, ASD total). For estimation of test-retest reliability, a test-retest sub-sample of 40 recordings from 20 individuals who had been recorded on two occasions less than one-month apart were randomly assigned to coders based on coder availability. Similarly, a sub-sample of 28 randomly selected recordings were identified and double coded by two coders in order to obtain estimates for inter-rater reliability. Reliability estimates were obtained from linear mixed models (xtmixed in Stata 14). Since it is not intended that items be interpreted independently, inter-rater and test-rest reliability analyses on individual items were not conducted.

To assess the validity of the BOSCC as a measure of relevant change, exploratory t-tests (paired) with an alpha of .05 were used to examine whether significant amounts of change in BOSCC and ADOS scores were present from the first to last observation. To include the multiple observations available on the same individual (see Table 2), growth curve models were fitted to all the available data on each child for the BOSCC ASD total, the VABS communication score, the MSEL receptive language score and the ADOS CSS (treated as a 10-point ordinal scale).

Analyses were also conducted on the BOSCC SC domain. For each participant in turn, a linear regression was fitted and the coefficient associated with the age at assessment was used as the average rate of change score for that participant.

[Insert Figure 1]

## Results

*Exploratory Factor Analyses.* Exploratory Factor Analysis of 308 codings from 56 participants of the 12 ASD items, of which the last three items were treated categorically, gave eigenvalues of 5.48, 1.58, and 1.05 and RMSEA values of 0.107, 0.067, and 0.037 for the one, two, and three factor solutions, respectively. See Tables 3 and 4 for details of EFA results. The two-factor solution was chosen as a plausible parsimonious fit for the data and for use in subsequent analyses because it had eigenvalues substantially greater than 1, a sufficient RMSEA value under 0.07 (Browne & Cudeck, 1993), and because it overlaps with the two-factor solutions (Social-communication and RRB) found in ASD literature (Guthrie, Swineford, Wetherby, & Lord, 2013; Mandy, Charman, & Skuse, 2012; Shuster, Perry, Bebko, & Toplak, 2014). Factor 1, the Social Communication domain, consisted of items 1-8. Although some studies suggest that play is a separate factor (Boomsma et al., 2008; van Lang et al., 2006), the play item, which cross-loaded both on factor 1 and 2, was placed in the RRB domain (items 9-12) for subsequent analyses due to item content that most closely relates to play with materials rather than social aspects of play. The two domains (Social Communication and RRB) will be referred to in subsequent analyses as well as the ASD total (including all ASD items 1-12). See Figure 2. As described above, the three items related to Other Abnormal Behaviors were not included due to the rare presentation of these behaviors in this sample of children.

[Insert Figure 2]

*Reliability Analyses.* For the subset of 20 children who received two videos separated by less than one month (40 videos), the estimated test-retest reliabilities were high: 0.87 for the Social-Communication domain, 0.79 for the RRB domain, 0.90 for the ASD Total. The estimated interrater reliability from the 28 videos randomly selected for double-coding was very high for Social Communication and RRB domains, as well as for the ASD Total, with ICCs ranging from 0.97 to 0.98.

[Insert Tables 3 & 4]

*Validity Analyses.* Overall, results of paired t-tests indicated that from first to last BOSCC observation (n=50), statistically significant changes were found in the ASD Total ( $M_{\text{change}}=-2.09$ ) [ $t(49)=2.23, p<0.05$ ], although changes in the separate SC and RRB domains were not significant. In contrast, paired t-tests from first to last ADOS observation (n=41) indicated that there were no statistically significant differences in ADOS CSS ( $M_{\text{change}}=-0.29$ ), ADOS SA CSS ( $M_{\text{change}}=-0.41$ ), or ADOS RRB CSS ( $M_{\text{change}}=+0.42$ ) scores. Results of whole sample random effects analyses indicated that the average rate of change each month in the ADOS CSS score was 0.055, which corresponded to an effect size of -0.025 per month. The average rate of change in the BOSCC ASD Total was -0.711 per month, corresponding to a substantially larger effect size of -0.061 for the monthly rate of change. Corresponding values for the BOSCC SC domain score were -0.57 and -0.063. Cross-sectionally, the BOSCC ASD Total and the ADOS CSS score were strongly associated (Pearson correlation of 0.48, cluster robust  $p<0.001$ ). The MSEL Receptive Language and VABS Communication Standard scores, chosen as additional measures of social-communication change, showed highly correlated change scores ( $r=0.69, p<0.001$ ). For the ADOS CSS change, as expected (because the CSS attempts to control for language levels) evidence for convergent validity with the MSEL Receptive Language and the VABS

Communication Standard score was neither significant nor consistent, while for the BOSCC ASD total, correlations were in the expected direction and, in the case of the MSEL Receptive Language, approached significance ( $r=-0.35$ ,  $p=0.05$ ).

Discriminant validity and coding contamination from maternal education and family income was tested by examining their association with the BOSCC scores when included as fixed predictors within a mixed effects model for the repeated BOSCC measures. No associations were found with any of the BOSCC Social Communication ( $\chi^2(2)=1.94$ ,  $p=0.38$ ) or RRB ( $\chi^2(2)=1.75$ ,  $p=0.42$ ) domains nor the ASD Total ( $\chi^2(2)=1.53$ ,  $p=0.47$ ). There was also no association of maternal education and family income with the ADOS CSS ( $\chi^2(2)=3.40$ ,  $p=0.18$ ).

*Post-Hoc Analyses.* Given the phenotypic heterogeneity of ASD, it was expected that not all children would respond to treatment (Rogers & Vismara, 2008). Therefore, responders and non-responders were identified based on changes from first to last observation on the basis of other measures of social and communication skills used as outcomes in previous studies (MSEL, VABS, ADOS; Dawson et al., 2010; Wetherby et al., 2014). Convergent validity was assessed using t-tests comparing the amount of change in BOSCC SC and RRB domains and ASD Total between responder and non-responder groups.

In the first analysis, responders were defined based on MSEL Receptive Language and VABS Communication Standard Scores, consistent with changes observed in these measures in recent intervention trials (Dawson et al., 2010; Wetherby et al., 2014). Specifically, children who increased MSEL Receptive Language Standard scores by  $\geq 5$  points (1/2 standard deviation) were defined as responders ( $n=15$ ) while the remaining children were defined as non-responders ( $n=21$ ). Second, using the VABS standard communication score, children were defined as responders if they demonstrated an increase of  $\geq 8$  points ( $n=16$ ), while the remaining children

were defined as non-responders (n=15). Third, responders were defined based on whether their ADOS CSS score decreased by 1 or more points (n=16), while the remaining children were defined as non-responders (n=25). As Figure 3 shows, BOSCC scores consistently demonstrated larger decreases in the MSEL and VABS responder groups compared to the MSEL and VABS non-responder groups. T-tests comparing the amount of change in BOSCC scores between the groups indicated that the MSEL responder group demonstrated significantly more change in the BOSCC SC domain and ASD Total than the MSEL non-responders group (See Figure 3). Results of t-tests also indicated that the VABS responder group demonstrated significantly more change in the BOSCC RRB domain and ASD Total than the VABS non-responder group. In contrast, BOSCC domains and the ASD total scores showed similar amounts of change in both ADOS CSS responder and non-responder groups (non-significant results).

[Insert Figure 3]

Last, in order to assess whether decreases in the BOSCC domain scores align with clinician's impressions of improvement, BOSCC scores for six children participating in an early intervention trial at Y (DeGeorge, Dufek, & Lord, in prep) were separated into responders and non-responders based on CGI scores. Specifically, four children received CGI scores of "much improved" (responders) while two children received CGI scores of "no change" (non-responders). As shown in Figure 4, with the exception of the BOSCC RRB domain, from first to last time point ( $M_{\text{months}}=8$ ), BOSCC scores for the CGI responders consistently decreased more than the CGI non-responders. Given the small sample size, no statistical analyses were conducted on these groups.

[Insert Figure 4]

## Discussion

Results of these initial analyses suggest that the BOSCC is a promising outcome measure that is sensitive to more subtle changes in social communication behaviors over time than several established alternatives. To our knowledge, the BOSCC is the first brief, observation-based measure of treatment response specific to social communication behaviors. These analyses of the psychometric properties of the BOSCC indicate that the BOSCC has adequate to excellent inter-rater and test-retest reliability, consistent with other work using an earlier version (Kitzerow, Teufel, Wilker, & Freitag, 2015). Several items that in an early version of the BOSCC demonstrated adequate, but relatively lower, reliability (Kitzerow, Teufel, Wilker, Freitag, 2015) have since been modified and are represented in this paper. A two-factor model, consistent with models of ASD symptoms, supporting a Social Communication domain separate from RRBs (Guthrie et al., 2013; Mandy et al., 2012; Shuster et al., 2014), fitted the item-data satisfactorily. The separation of the two domains allows future researchers to explore changes in social communication skills in children with social and/or communication impairments without ASD.

Results presented here provide a first indication that the BOSCC has convergent validity with social communication changes seen in other measures, including a parent report measure (VABS), standardized cognitive measure (MSEL), and clinician's impression (CGI). Although the separate SC and RRB domains may prove useful in non-ASD populations or when assessing change specific to one domain, results suggest that improvements (decreases) in the BOSCC ASD Total (items 1-12, combining Social Communication and RRB domains) most consistently converged with improvement (increases) in other standard measures of communication, such as receptive language skills as measured by the MSEL and adaptive communication skills as measured by the VABS. This suggests that the BOSCC ASD Total may be the most appropriate

domain to identify improvement in young, minimally verbal children with ASD. This needs to be confirmed in future work with larger samples.

In particular, BOSCC scores appear to be more sensitive to changes in social communication behavior than the ADOS CSS, and hence more successful in identifying changes in response to treatments over shorter periods of time (Dawson et al., 2010; Shumway et al., 2012; Thurm et al., 2015). Furthermore, the BOSCC ASD Totals and the ADOS CSS scores were highly correlated with each other, although there was not a significant correlation between change in the BOSCC and change in the ADOS CSS. These findings suggest that the BOSCC may be measuring behaviors, especially subtle behaviors that are improving, differently than the ADOS. Or this finding may be related to the limited range of change found in the ADOS CSS scores, consistent with other studies (Dawson et al., 2010), or limited range of scores overall. It should be noted that, despite the high correlation between the BOSCC score and ADOS CSS score, the BOSCC is not intended to be a measure of ASD severity, nor is it a measure intended for diagnostic classification. Rather, the BOSCC was developed to capture nuanced social communication behaviors that may change over relatively brief periods of time.

In line with the goals for development, the BOSCC is relatively easy to code, unlike other commonly used measures (Bolte & Diehl, 2013). In fact, our group has been successful at training several undergraduate-level research assistants as well as one highly motivated high school student to code the BOSCC reliably. In addition, the BOSCC does not rely on parental report of symptoms, minimizing measurement bias (Anagnostou et al., 2015; Bolte & Diehl, 2013; Guastella et al., 2015).

Given the subtlety of social communication behaviors that the BOSCC measures, it is currently recommended that each BOSCC video segment (5 minutes) be viewed twice and the

second set of codes should be used for interpretation. This method takes approximately 30 minutes per video. Although our group found little difference in averaged totals between the first and second set of codes (data not presented), changes at the item level were present. In addition, coders reported having more confidence in their coding after their second viewing.

Any changes in a child's behavior during an interaction with a parent must be considered in light of changes in parental behavior. Several studies confirm that the parent-child interaction is bi-directional--the child's behaviors impact the parent and vice versa (Ginn, Clionsky, Eyberg, Warner-Metzger, & Abner, 2015; Rutgers, Bakermans-Kranenburg, van Ijzendoorn, & van Berckelaer-Onnes, 2004; Siller & Sigman, 2008; Slaughter & Ong, 2014; Zhou & Yi, 2014). A recent parent-focused intervention study found that changes in ASD symptoms, as measured by the ADOS CSS, were mediated by parental synchrony (Pickles et al., 2015). Similarly, work has also shown that children's language development may be influenced by a parent's responsiveness during play interactions (Siller & Sigman, 2008). Another study found a high correlation between the quality of the parent-child interaction and the child's ASD severity (using the ADOS CSS; Hobson, Tarver, Beurkens, & Peter Hobson, 2015). Our study did not assess whether the parent's behavior significantly impacted the child's BOSCC scores or if the child's severity of ASD or other behaviors impacted parental behavior. Given these potential confounds, some researchers may choose to have an examiner who is blind to the child's treatment status interact with the child during the BOSCC. If the parent is chosen as a BOSCC partner, researchers should consider collecting additional measures of generalization and/or parental behaviors that may contribute to observed changes in the child's behavior (Pickles et al., 2015).



The BOSCC was developed primarily as a measure of changes in social communication behaviors. As mentioned earlier, only three items on the BOSCC attempt to capture RRB behaviors across a continuum. Item distributions indicate that obtaining a continuum for these behaviors was a challenge. It may be that these behaviors are either clearly present or not (with little variation in between) or that subtle variations in these behaviors are difficult to capture, especially within a five minute time frame. Though still adequate, the RRB domain score demonstrated lower inter-rater reliability than the social communication domain, consistent with earlier iterations of the BOSCC (Kitzerow, Teufel, Wilker, Freitag, 2015). Notably, it was the ASD Total (combining SC and RRB domains) that was most successful in identifying changes, indicating the importance of these behaviors at least in this ASD sample. Perhaps this is a result of the strong relationship between these domains in the ASD population (Richler, Huerta, Bishop, & Lord, 2010). The RRB subdomain on the BOSCC may not prove to be a useful subdomain in which to measure change but additional studies are needed. In the meantime, it may be helpful to use other measures of RRB behaviors to complement the BOSCC, such as the Repetitive Behavior Scale-Revised (RBS-R; Lam & Aman, 2007). Although there are biases with the reliance on such a likely unblinded a parental response measure, concordance with the BOSCC may prove useful in both providing validity for the BOSCC and in confirming the presence of meaningful change.

Although the initial results of the BOSCC are promising, they should be interpreted in light of several limitations of this project, including the small sample size. This study focuses on a sample of 56 toddlers and preschoolers with ASD, with even smaller samples of children with multiple observations of other measures (e.g., VABS, MSEL, ADOS) used for convergent validity. This paper did not explore specific treatment or control conditions. We hope to expand

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4 this work to a larger sample comparing different interventions, employing the BOSCC as an  
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6 independent measure of treatment response. In addition, our limited sample did not allow for  
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8 analyses of differences by sex, race, or ethnicity. Perhaps given the context of free-play with a  
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10 parent, our items related to Other Abnormal Behaviors elicited few positive codes. However,  
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12 other researchers may want to consider these items in future analyses since these behaviors may  
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14 impact social communication and RRB behaviors captured in other codes or be more common in  
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16 other contexts. Our ongoing work and the work of other researchers (Fletcher-Watson et al.,  
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18 2015; Kitzerow, Teufel, Wilker, & Freitag, 2015) will continue to provide larger samples across  
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20 multiple sites in order to contribute to our understanding of the value and limitations of the  
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22 BOSCC.  
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28 Although this study focused on a sample of children with diagnoses of ASD, future work  
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30 should also address whether the BOSCC can capture changes in children with social  
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32 communication deficits who do not have ASD (e.g., Social/Pragmatic Communication disorder,  
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34 Social Anxiety Disorder). Our group is also working on several lines of research related to the  
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36 development of the BOSCC, including applying the BOSCC to school-age children who have  
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38 limited speech, expanding the BOSCC to verbally-able individuals, and modifying the BOSCC  
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40 codes so that they can be applied to segments of ADOS videos (allowing researchers to explore  
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42 pre- and post-treatment ADOS videos from previously collected data). We hope that the BOSCC  
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44 can provide unique, objective observational data and bolster the value of other measures  
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46 commonly used (Anagnostou et al., 2015) in the assessment of the efficacy, and course of  
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48 treatments aimed at improving social communication skills.  
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## Figures

Figure 1. Distributions for 12 ASD BOSCC Items (Averaged across Segments A and B).

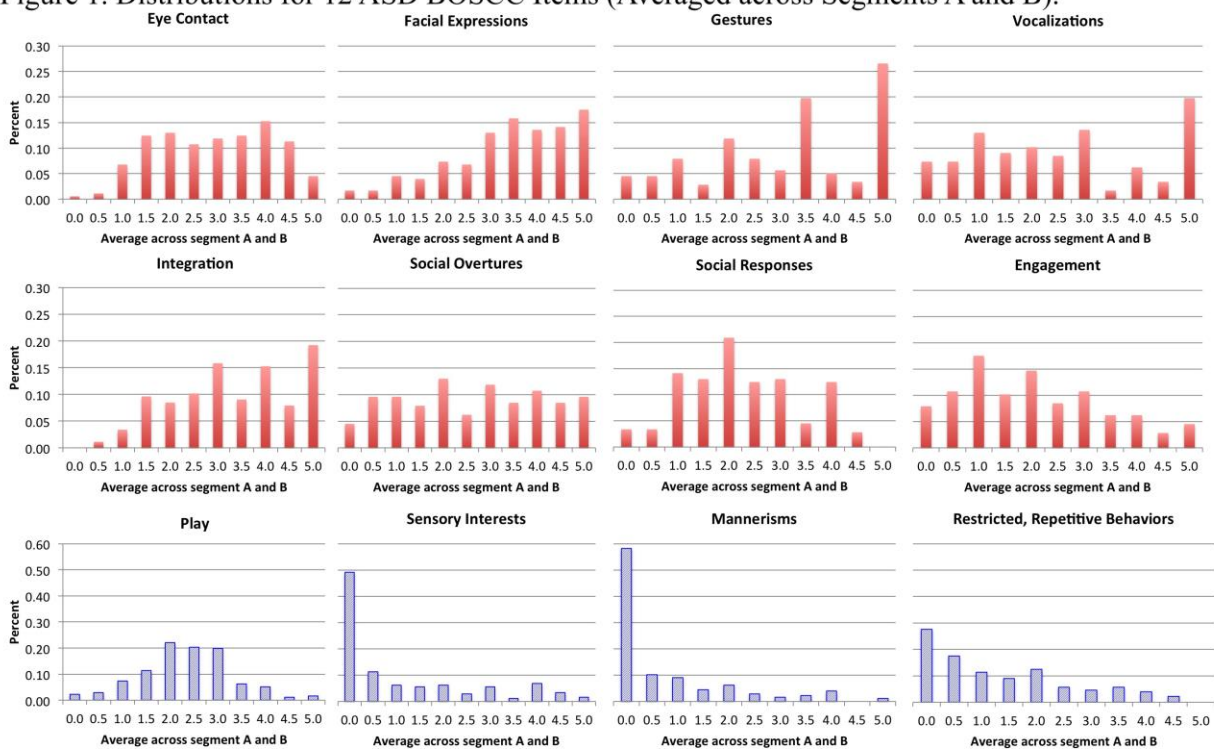


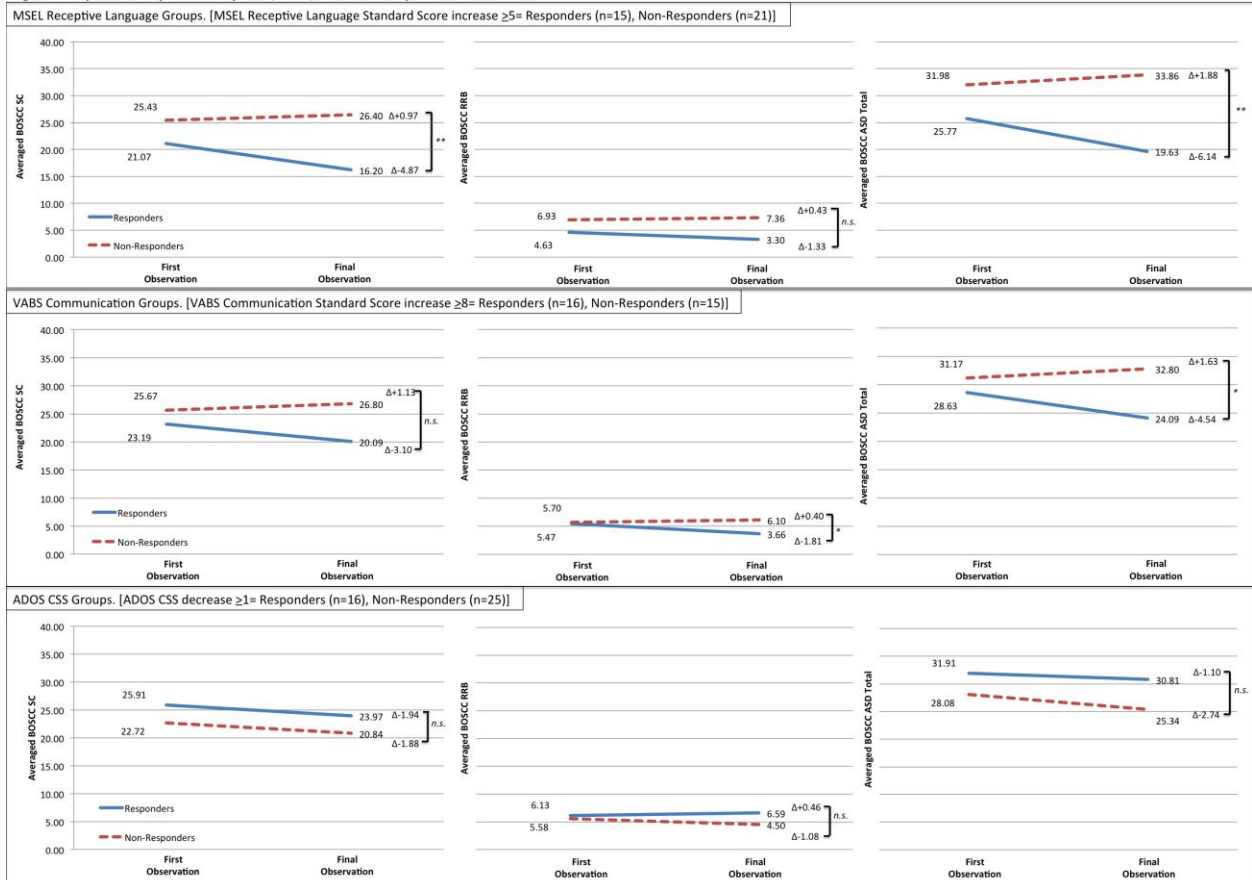
Figure 2. BOSCC Items, Domains, and Total.

		Domain	Total
1	Eye Contact	Social-Communication	ASD
2	Facial Expressions		
3	Gestures		
4	Vocalizations		
5	Integration of Vocal and Non-Vocal		
6	Social Overtures		
7	Social Responses		
8	Engagement		
9	Play	RRB	
10	Unusual Sensory Interests		
11	Hand/Finger/Body Mannerisms		
12	Repetitive/Stereotyped Interests/Behaviors		
13	Activity Level	Other Abnormal Behaviors	
14	Disruptive Behavior/Irritability		
15	Anxious Behaviors		

Note: ASD= Autism Spectrum Disorder; RRB= Restricted, Repetitive Behavior/Interest

Figure 3.

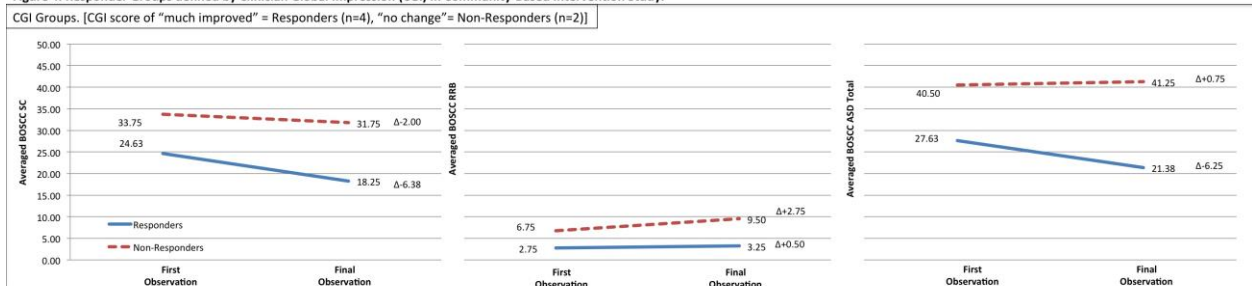
Figure 3. Responder Groups Defined by MSEL, VABS, or ADOS in Early Intervention Studies.



Note: \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ ; ADOS= Autism Diagnostic Observation Schedule; ASD= Autism Spectrum Disorder BOSCC Domain; BOSCC= Brief Observation of Social Communication Change; CSS= ADOS Calibrated Severity Score; MSEL= Mullen Scales of Early Learning; n.s.= not significant; RRB= Restricted, Repetitive Behaviors BOSCC Domain; VABS= Vineland Adaptive Behavior Scales

Figure 4.

Figure 4. Responder Groups defined by Clinician Global Impression (CGI) in Community-Based Intervention Study.



Note: ASD= Autism Spectrum Disorder BOSCC Domain; BOSCC= Brief Observation of Social Communication Change; CGI= Clinician's Global Impression-Improvement; RRB= Restricted, Repetitive Behaviors BOSCC Domain; SC= Social Communication BOSCC Domain



Tables.

Table 1. First Observation Information (n=56).

	Mean (SD)
Age (months)	28.9 (10.5)
VABS (Standard Score)	
Communication	78.7 (17.5)
Socialization	79.0 (12.1)
Daily Living	84.0 (13.3)
Motor Skills	89.1 (13.8)
MSEL (Ratio)	
VIQ	62.9 (21.9)
NVIQ	78.5 (23.7)
ADOS	
CSS	7.6 (2.0)
SA CSS	7.7 (2.1)
RRB CSS	7.0 (2.1)
	n (%)
Sex (Males)	44 (79)
Race (Caucasian)	34 (61)
Ethnicity (Hispanic)	6 (11)
Maternal Education (4+ years College)	30 (57)

Note: ADOS= Autism Diagnostic Observation Schedule; CSS= Calibrated Severity Score; MSEL= Mullen Scales of Early Learning; RRB CSS= Restricted, Repetitive Behavior Calibrated Severity Scores; SA CSS= Social Affect Calibrated Severity Scores; SD= Standard Deviation; VABS= Vineland Adaptive Behavior Scales

Table 2. Information about Assessments Gathered.

Assessment	N with $\geq 2$ Observations	# of Observations (Mean)	# Months Between Observations (Mean)
BOSCC	50	3.4	5.9
ADOS	41	2.5	5.9
MSEL	36	2.0	9.2
VABS	31	2.1	9.5

Note: ADOS= Autism Diagnostic Observation Schedule; BOSCC= Brief Observation of Social Communication Change; MSEL= Mullen Scales of Early Learning; VABS= Vineland Adaptive Behavior Scales

Table 3. Brief Observation of Social Communication Change (BOSCC) Exploratory Factor Analysis Model Comparison.

Model ( <i>df</i> )	$\chi^2$ Test of Model		p	Eigenvalue	RMSEA
	Fit	df			
1-Factor (54)	221.29	54	<.001	5.48	0.107
2-Factor (43)	101.85	43	<.001	1.58	0.067
3-Factor (33)	46.7	33	0.057	1.05	0.037

Note: df=degrees of freedom; RMSEA= Root mean square error of approximation; \*<.05, \*\*<.01, \*\*\*<.001

Table 4. 1, 2, and 3-Factor Model Factor Loadings for Brief Observation of Social Communication Change (BOSCC) Items.

Item Name (abbreviated)	1-Factor Model	2-Factor Model (promax)		3-Factor Model (promax)		
	Factor 1	Factor 1	Factor 2	Factor 1	Factor 2	Factor 3
Eye Contact	<b>0.66</b>	<b>0.78</b>	-0.06	<b>1.00</b>	-0.16	0.11
Facial Expressions	<b>0.51</b>	<b>0.62</b>	-0.09	<b>0.59</b>	0.05	-0.02
Gestures	<b>0.50</b>	<b>0.73</b>	-0.21	<b>0.42</b>	0.36	-0.27
Vocalizations	<b>0.77</b>	<b>0.63</b>	0.24	0.10	<b>0.80</b>	-0.05
Integration of Vocal and Non-Vocal	<b>0.84</b>	<b>0.87</b>	0.07	<b>0.65</b>	0.32	0.05
Social Overtures	<b>0.79</b>	<b>0.71</b>	0.16	<b>0.51</b>	0.34	0.09
Social Responses	<b>0.76</b>	<b>0.56</b>	0.31	0.14	<b>0.67</b>	0.05
Engagement	<b>0.62</b>	<b>0.40</b>	0.32	-0.06	<b>0.72</b>	0.03
Play	<b>0.50</b>	0.27	0.32	-0.15	<b>0.69</b>	0.01
Unusual Sensory Interests	<b>0.57</b>	-0.07	<b>0.85</b>	0.09	-0.05	<b>0.95</b>
Hand/Finger/Body Mannerisms	<b>0.40</b>	-0.12	<b>0.67</b>	-0.03	0.09	<b>0.55</b>
Repetitive Interests/Behaviors	<b>0.58</b>	0.17	<b>0.55</b>	0.06	0.32	0.38

Note: All factor loadings  $\geq 0.4$  shown in bold.

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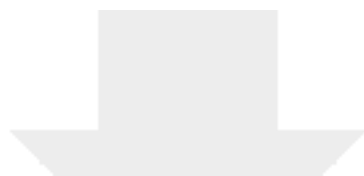
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*Conflict of Interest*

Author C.L. receives royalties from the sale of the ADI-R and the ADOS-2. All royalties related to the research were donated to a non-profit organization. No other authors have conflicts of interest with regard to this study.

*Author Contribution*

Author R.G. participated in study conceptualization, measure development, data coding, analysis, interpretation, and manuscript preparation. Authors T.C. and C.C. participated in conceptualization and development of the Brief Observation of Social Communication Change (BOSCC). Author K.M. and S.D. participated in study conceptualization, measure development and data coding. Author A.P. assisted with data analyses and interpretation. Author C.L. participated in study conceptualization, measure development, data analysis and interpretation, and manuscript preparation.



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